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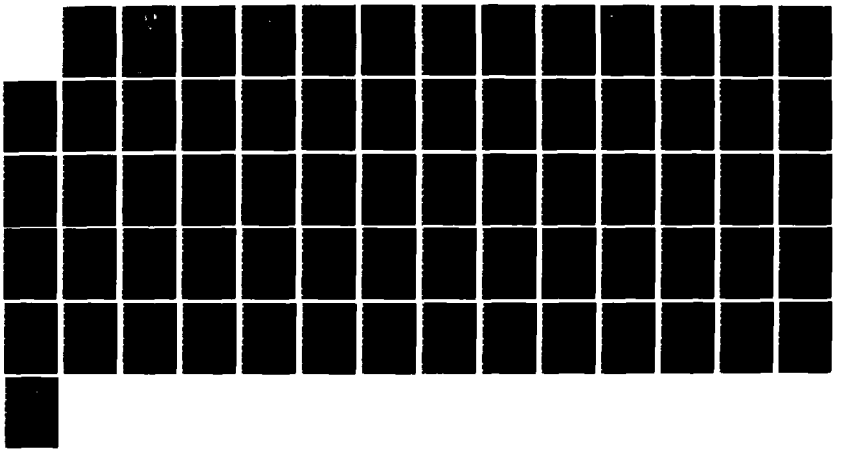

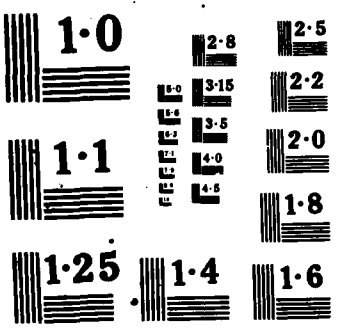

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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

GUIDELINES TO ESTABLISH
QUALIFICATIONS
FOR COMPUTER RELATED JOBS

Major Steven J. Cristiani 86-0620

"insights into tomorrow"

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Computer based systems play a vital role in the accomplishment of the Air Force mission. Problems with the development, use, and maintenance of these systems threaten operational readiness. Many of these problems can be attributed to a lack of qualified personnel. This study provides general guidelines about the education and experience background required to perform in computer related jobs. Recommendations are given concerning initiatives to improve the human resource situation.

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PREFACE

This study is about human skills, cognitive abilities, decision making, and how to improve these abilities. The specific area of interest is that of computer related jobs. Unfortunately, the study of human performance, evaluation, and learning is not an exact science. Facts, figures, and equations cannot provide precise insight into the solution of human problems. Compounding the problem is the fact that our understanding of the computer as a tool and an object of engineering development is not mature. As a result, we can only provide some general insight into the problems of how to determine job qualifications. We base this insight on general principles, molded by intuition and experience.

My intuition and experience has been formed in the last thirteen years working with and for a wide variety of people. Some have been competent and dedicated, others have lacked one or both of these characteristics. All have given me the spark of interest necessary to put my thoughts on paper.

I would like to thank my advisor, Lt.Col. Macey, for his assistance in getting me started on the right track on the most important subject of this study: education.

ABOUT THE AUTHOR

Major Steven J. Cristiani is a career Air Force officer interested in improving the operational capability of the Air Force through the effective use of computer based systems.

Major Cristiani was first introduced to computers and programming while in high school in 1968. For the last sixteen years he has been studying, practicing, and teaching the design, development, use, operations, and maintenance of computer based systems. He has worked with a wide range of systems from microcomputers to large mainframes. His experience covers a wide range of applications, with several years spent both in data automation activities as well as the embedded computer systems arena. He has had a broad base of responsibilities including systems analyst, project team leader, project manager, contract monitor, lead software engineer, and section chief. While assigned as an Assistant Professor of Computer Science at the U.S. Air Force Academy, he developed and taught courses in systems analysis, systems design, and software engineering.

Major Cristiani graduated from the U.S. Air Force Academy in 1973 with a degree in computer science. He also holds a master's degree in computer science and engineering from UCLA. He is a graduate of Squadron Officers' School and the Air Command and Staff College.

Major Cristiani is a member of the Air Force Association, the Association of Computing Machinery, and the IEEE Computer Society. He holds the Certificate in Data Processing from the Institute for Certification of Computer Professionals.

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EXECUTIVE SUMMARY

Part of our College mission is distribution of the students' problem solving products to DoD sponsors and other interested agencies to enhance insight into contemporary, defense related issues. While the College has accepted this product as meeting academic requirements for graduation, the views and opinions expressed or implied are solely those of the author and should not be construed as carrying official sanction.

"insights into tomorrow"

REPORT NUMBER 86-0620

AUTHOR(S) MAJOR STEVEN J. CRISTIANI, USAF

TITLE GUIDELINES TO ESTABLISH QUALIFICATIONS FOR COMPUTER RELATED JOBS

I. Purpose: To establish general guidelines that will assist management in determining educational and experience qualifications for Air Force computer related jobs. These same guidelines can be used to plan training and education programs for those jobs. Computer related refers to all categories of jobs where computers are employed, regardless of the type of job or application.

II. Problem: Computer based systems form an essential element of every operational and support mission area in the Air Force. Unfortunately, the development, use, and maintenance of these computer based systems have been prone to errors, cost overruns, and schedule slippages. This has had an adverse effect on the operational readiness of the Air Force. One of the most serious causes of these problems is the lack of sufficient, qualified individuals in computer related job positions. A deeper understanding of the qualifications necessary for these jobs will contribute to solving the problems of computer based systems.

III. Data: There are large numbers of computer related jobs in the Air Force encompassing many different specialities. Most of these jobs are very similar to ones in the private sector. The various tasks of these jobs can be categorized into user, operations, administrative support, maintenance, development, management, and staff areas. The user, operations, and

administrative support tasks are relatively non-complex, and can be accomplished with knowledge and skills gained from specialized training and experience. The maintenance task is more complicated, and requires more formal education prior to the specialized training and experience. The development task is very complex, not well understood, and in a constant state of change. Studies of development establish its similarity to the engineering fields. Knowledge of psychology and education establish that a broad based educational background is important for jobs like development and engineering. Such educational programs are in existance, although not extensively present in the backgrounds of Air Force development personnel. In addition to a requirement for a broad technical background, developers need knowledge of the application domain in which they are working. Other knowledge requirements in the areas of management, large scale systems, Air Force policies and procedures, etc. can be obtained by a proper mix of training and experience. Management and staff job tasks are similar to development tasks in their educational and experience requirements because of the broadness of the decision making domain. There are programs being initiated to strengthen the quality of computer personnel, however, not all of them will accomplish their objective without a change in direction based on modern techniques and approaches. A possible diversion to the progress being made in this area is the proliferation of microcomputers and end-user computing. This decentralized computing initiative, although potentially of great benefit, threatens to repeat many of the problems currently plaguing the computer based system arena.

IV. Conclusions: The problem with computer personnel can be solved with a coordinated program of technology assessment and job analysis. The Software Technology for Adaptable Reliable Systems (STARS) program will accomplish this goal with adequate support. Other programs such as Project Boldstroke will assist in establishing a wide base of support for intelligent application of computer systems.

V. Recommendations: The Air Force should improve the quality of its computer resource personnel by strengthening the requirements for the various Air Force specialities. These improvements should be based on accredited professional degree programs, a thorough understanding of computer based system development, use, and support, and the analysis of modern technology trends. Programs such as STARS and Boldstroke should be promoted and supported. Initiatives to improve the personnel quality should be examined objectively for the proper approach to solving the problems at hand.

Chapter One

INTRODUCTION

Computer usage has expanded in all areas of the U.S. Air Force. From the office environment at every installation to the satellites orbiting in space, the computer and its associated systems play a vitally important role. Computers have increased the productivity of administrative personnel, provided operational commanders with immediate access to status of their forces, and provided capabilities to the current generation of weapon systems beyond the imagination of airpower pioneers. But, with these accomplishments have come a number of critical issues that tarnish the record of success and threaten the national security.

Problems with computer based systems have been recognized for many years. Symptomatically these problems manifest themselves by systems that never seem to work correctly or as the user would like them to, that are much too expensive to build and maintain, and that always takes longer to create, modify, install, and learn to use than anyone predicted. As these problems began to show themselves early in the history of computers, and their presence seemed to be so universal, increasing attention was paid to finding their solutions (11:chap 1; 13:chap 2).

Many initiatives have been started to combat the problems mentioned above. In the 1960's, as the use of high order languages in programming became widespread, an effort to standardize resulted in the government-wide mandate for COBOL. Later in the 1970's the USAF put emphasis on the management control of software development and the use of structured programming. The issue of programming languages was tackled again in the development of Ada. Simultaneously, new standards in the areas of computer instruction set architecture, communication protocols, development methodologies, and documentation were put into place. Most recently the Department of Defense has embarked upon an ambitious program called STARS (Software Technology for Adaptable, Reliable Systems) (66:1-4). Unfortunately, the problems associated with computer oriented systems have not gone away; in fact, the potential for serious damage has increased. This is not to say that the initiatives have been totally ineffective. Rather, they have not adequately addressed the real causes of the problems. Among these is that of the shortage of well-qualified personnel.

Many studies have dealt directly with the issue of personnel qualifications. The shortage of qualified personnel has been identified as a problem area, but this is often underemphasized, and simple training programs are proposed as the solution (38:--; 65:--). There are three basic fallacies in this approach. First, it fails to recognize the requirement for a thorough needs

assessment before defining the training program. Second, when a needs assessment is accomplished, it assumes the current way of doing the job is correct. Finally, it presupposes the solution to be technical training. One current effort that avoids these traps is the STARS program, which has an extensive human resources area of investigation. STARS, however, is subject to funding uncertainties. Even with adequate funding it cannot be expected to produce useable results for the next two to three years. In addition, it is primarily directed toward the mission critical application area, thereby omitting major segments of the computer application domain (28:--; 64:--).

This study provides some near term assistance for dealing with the human resource problem in computer related areas of the USAF. The objective is to provide a set of guidelines to allow knowledgeable supervisors to classify their computer related positions, define the qualifications for those positions in terms of knowledge and skills derived from experience and education, determine methods for obtaining qualified personnel, and establish the needs for education and training when those are the appropriate mechanisms. In addition, the study makes recommendations about Air Force wide computer personnel management policies.

This report develops the information to accomplish the objectives stated above, and provides recommendations on the human resource problem of computer based systems. The remainder of this chapter will address the assumptions, limitations, and constraints on the study. Chapter Two will establish the importance of cost effective computer hardware and software employment in the USAF environment. Chapter Three will define the categories of jobs, their responsibilities and duties, and the general qualifications for each within the commercial sector as well as the USAF. Chapter Four will describe several areas of importance to establishing a valid set of guidelines. Included are computer system fundamentals and concepts of learning and psychology. Chapter Five will define the target set of job tasks based on the information from the previous chapters. It will also set forth the guidelines necessary to establish the qualifications for these job tasks. Chapter Six will describe present USAF characteristics in relation to these general guidelines and qualifications. Finally, Chapter Seven will recommend actions to USAF management based upon the guidelines developed.

ASSUMPTIONS, LIMITATIONS AND CONSTRAINTS

There are literally thousands of different job titles that are computer related. Obviously, to attempt to address each one would be impossible. As will be shown later, the fact that there are so many computer related job titles contributes to the problems of personnel management. This paper will group the many

different job types into a small number of categories based on meaningful similarities and differences of the job types.

Specific positions often have valid qualification requirements that are very narrowly defined. Again, this paper cannot possibly address the vast numbers involved. Instead, it sets forth a series of guidelines that can be applied to specific job positions by the manager.

The importance of up-to-date technical knowledge is a major theme throughout this paper. Much of the data supporting this study would have been different five or ten years ago due to a rapidly changing technical baseline. Undoubtedly, this evolution will continue. As it does, the findings of this paper need to be carefully scrutinized for obsolesence. It must be cautioned, however, that one of the other major themes presented here deals with the existence of a set of basic, unchanging characteristics of computers. These cannot be overlooked when updating the findings of this paper.

As a relatively new field of science and engineering, the computer 'business' cannot be expected to function and be understood with the same confidence as other professions. There are two important ramifications of this. First, much of the current body of professional practitioners made their way into the 'business' without formal computer related backgrounds (51:14). The results of this study should not be construed as a wholesale denigration of this group. As will be pointed out later, the knowledge itself is more important than the source from which it was obtained. The primary purpose of this paper is to identify some approaches to alleviate the problems of the past. This can be done by infusing the system with qualified individuals who are at the beginning of their careers. Second, as stated above, society's understanding of computers will continue to grow. As it does, a more competent approach to evaluating personnel qualifications will emerge than this short paper can hope to provide.

The body of knowledge about computers is immense, and growing rapidly. This study does not attempt to present or summarize the breadth or depth of the field, as this is obviously impossible. This paper will, however, provide reference to some of the most important concepts of computers which have a significant bearing on the determination of personnel qualifications.

This study applies to all application areas of computer use. One of the most damaging tendencies has been for technocrats and users alike to think of every application, every computer operation, every development to be unique. One of the most significant issues addressed by this study is the similarity between applications and situations that are seemingly quite different. Only through recognizing when situations are the same and when they are really different can sound decisions be made about the development and employment of computer based systems.

Certainly there are important differences between the operational flight program of the B-1B and the word processing program used to produce this report. But, there are also similarities, and the key to effective use of development resources is to be able to understand both.

This study addresses all areas where computer technology is applied. The Air Force has recently embarked upon a reorganization of its data automation, communications, and office automation agencies, career fields, and policies. In keeping with the trend of industry and the rest of government, the Air Force is using the term 'Information Systems' to describe this new association (54:--). There are many applications of computer technology outside the information systems area, however. The relevant issue is that computer technology is common to all areas in one form or another. As such, this paper will not artificially segregate pertinent support and findings simply because they have been historically categorized in one area or another.

This report does not provide a handbook's 'how to' approach to personnel management. Such approachs reduce the complex management process to an oversimplified checklist. The guidelines presented here form an additional set of factors to be used by intelligent leaders in performing their personnel management tasks. A handbook might be construed as providing information for a non-experienced (unqualified) person to use. Staffing of an organization in the computer related business is highly dependent on the circumstances. This implies the manager must have considerable knowledge about the circumstances to make wise decisions. No simple set of guidelines can help the unqualified manager in this instance.

Although this study concentrates on job tasks and qualifications that are computer related, this should not be construed as disregarding qualities of leadership required in professional Air Force officers, airmen, and civilians. These qualities are essential in all Air Force jobs. It should be remembered, however, that one quality of leadership is knowledge of the job. The importance of technology has not diminished this requirement (31:--).

As described in Chapters Three and Five, the Air Force uses military and civilian personnel extensively in a wide variety of computer related jobs. This study assumes those job types will exist in the near future.

Finally, this report tends to concentrate on the software aspects of computer based systems.This is only because software has been the primary problem area. The relationship of software to hardware and to the application cannot be overstressed. It is these relationships that make software the focus of most computer system studies (74:--;69:--;28:--).

Chapter Two

IMPORTANCE of COST EFFECTIVE COMPUTER EMPLOYMENT

Before examining the types of job responsibilities and qualifications, a review of the importance of computer based systems in the Air Force is required. This chapter will discuss the role these systems play, the benefits they provide, the level of emphasis placed on them by the Air Force, the scope of problems encountered in the use of computer based systems, and finally, the reasons for taking a specific look at the human resource area.

ROLE OF COMPUTER BASED SYSTEMS

Categories of Systems.

The groupings of system types presented here are somewhat arbitrary, and based on commonly accepted definitions in the computer field. The categories are important for several reasons. They serve as a general model with which specific systems can be identified. They also serve as a framework for understanding the importance of application areas to the development and use of computer based systems. This is significant in comprehending the importance of differences and similarities between major areas of computer use. It should be emphasized that any specific computer based system may logically be categorized in more than one of the areas.

1. Management Information Systems. A management information system is one which provides information on the health and operation of the organization to the decision makers. Depending on the business of the organization, this information can be of a wide variety and type. For example, commercial business is very interested in sales, costs, profits, etc. On the other hand, a military commander is concerned with information that tells him how many aircraft are mission capable, how many are awaiting spares, etc. Management information tends to be 'bottom-line' oriented in that it provides the manager with just that data necessary to make decisions. Decision support systems , a current 'high interest' area, are included in this group. Also, the domain of management oriented , knowledge based systems might be included. The problem of determining the information needs of management is one of the most difficult encountered in the system development. This has important implications for staffing an organization responsible for these systems (18:chap 3).

2. Information Management Systems. This category describes those applications where the system manages information for the operation of the organization. Typically, the working levels and middle management are the users of these systems. Also, this

category can be viewed as a subtier of management information systems in that it provides the raw data to the higher level tier for synthesis. The data maintained in an information management system is obviously that which describes the workings and purpose of the organization. The processes by which the data are manipulated are, in fact, a reflection of the operating policies of the organization. This impacts directly on the organizational knowledge required of personnel associated with a system.

3. Personal Productivity Systems. The purpose of these systems is simply to enhance the productivity of the person using them in whatever way possible. The most obvious example is the word processor which makes the job of document preparation, especially where multiple versions are created, much easier and faster to accomplish. Any system that automates a manual task could be classified as a personal productivity system. However, these systems are most often characterized by microcomputer applications since the stand-alone micro is truly a personal system for the duration of an individual's work session.

4. Analysis Support Systems. This category describes those systems that provide computational support to mathematical, scientific, and engineering applications. These are the traditional 'number-crunching' programs that operate on varying data sets and produce numerical answers as their end objective.

5. Process Control (real-time). The main distinguishing factors of real-time systems are that they are driven by the arrival of data and must process this data so that the results are available in some pre-defined, short period of time. The proper operation of the overall systems being supported is dependent on these computations being available when scheduled. The input and output devices associated with process control are often environmental sensors and physical control systems such as an aircraft's airspeed measurement system and control surfaces, respectively. The term real-time as used here is sometimes described as 'hard' to distinguish it from those systems where time dependency of the operation is not a requirement.

Application Areas.

The categories listed above separate systems into how they are used. The separation into application areas deals more with where they are used. Again, the categories defined here are based on common usage. There is overlap and duplication amongst them. A specific system might belong to more than one area.

1. Business Data Processing. The use of automated systems in business applications is one of the oldest and most extensive. Although the Air Force is not a business in the same sense as a private company, there are many 'business-type' applications suitable for computerization. Most of these are well known and

common to every large organization: personnel management, accounting and finance, contracting, etc. There are also some specialized applications that reflect the unique responsibilities of the military such as medical systems, food preparation, etc. In recent years the office automation area has generated increased interest throughout the Air Force. This area encompasses a wide variety of applications such as word processing, electronic mail, desktop managers, etc. The business data processing applications fall into the general system categories of information management systems, management information systems, and personal productivity systems. Historically, business systems were developed by applications programmers in COBOL and then used by the functional application area via batch or on-line interface. With the availability of microcomputers, ready-to-use application packages, and development tools suitable for end-user development, the nature of business application development is changing radically. Business systems are characterized by high volume input/output, with a lesser dependence on processing power. Many business applications are database oriented in one form or another.

2. Scientific/Engineering Support. The earliest application area to be put on a computer, this area still stands as one of the most important. Support to the engineer and scientist primarily involves numerical computation, and is usually constrained by the processing speed of the computer as opposed to the input/output capabilities. Laser, weather, and nuclear weapon research are among the many specific areas of scientific usage. Typical engineering applications include such things as aerodynamic and structural modeling, windtunnel data collection and analysis, and computer aided design. The scientific/engineering area is the one primarily targeted for application of supercomputers. The most common means of producing software for these applications is by the scientist/engineer himself, using FORTRAN. Applications are developed and run on all classes of computers, from micro to mainframe.

3. Command, Control, Communications. Although spanning a wide variety of applications, C^3 is customarily viewed as those functions relating specifically to the strengths, positions, and capabilities of the forces available to military commanders. Often the intelligence function is also added to this general category. These systems resemble the business applications area in many ways, especially their widespread database orientation. Typically, these systems rely on real-time communications and both local area as well as long haul networks. C^3 systems have traditionally been developed by large teams in a mixture of languages such as Jovial (various dialects), COBOL, and FORTRAN. This area is characterized mainly by information management and management information systems.

4. Operational Mission Support. The operational mission support area is not easily distinguished from the business

application area except that the systems are in a more direct support role to the mainline operational mission of the Air Force: flying. Functions such as maintenance, supply, flight planning, etc. are typical examples. Many of these applications are database oriented, programmed in COBOL, and run on a variety of systems, both mainframe and micro. These systems are a combination of information management and management information types.

5. Mission Critical. Previously known as embedded computer systems, the mission critical application area includes those in which the computer is integral to the operation of the larger system, as well as those systems which are predominantly the computer itself but which are dedicated to so-called mission critical applications such as missile early warning, intelligence collection, etc. The mission critical category is one which differentiates management approach more than unique differences in technology. The previously mentioned C^3 systems are actually mission critical systems as well. In addition to the characteristics attributed to C^3 systems, the embedded portion of mission critical systems are often real-time (in the 'hard' sense), subject to harsh environmental constraints, programmed in a variety of assembler languages, as well as FORTRAN, Jovial, etc., and are best described as process control type applications.

BENEFITS OF COMPUTER BASED SYSTEMS

Computers have become an integral part of virtually every function in the Air Force. Their sheer numerical presence is matched in importance by the enhanced capabilities they provide (69:chaps 1,2). These advantages can be put into two categories: advanced capabilities and increased productivity.

One of the most important advantages provided by automation is the increase in what can be accomplished. There are, quite simply, many functions which could not be performed without the assistance of computers. This capability enhancement is present in all categories and areas of use.

Examples of where new capabilities have been provided are numerous. Almost all of them are a result of the fundamental power derived from a computer's speed and memory capacity. For instance, the functions of air defense, missile warning, strategic command and control, autonomous vehicle navigation, and many of the intelligence gathering activities would not be possible or would not be useful without automated support. The importance of having technologically superior systems has become well known, and accepted as necessary to offset the numerical advantage in weaponry enjoyed by the Soviet Union.

It is widely held throughout the DOD that technically advanced systems can overcome numerical superiority, but only within certain limits. If either the numerical advantage becomes too great, or the technical edge is cut too much, the net assessment of superiority can shift. Recent estimates have put the U.S. computer technology lead at about three to five years over the Soviets, compared to a ten to twelve year advantage in 1975 (43:42).

The most common advantage attributed to automated systems is that they increase productivity, decrease costs, and provide an overall more cost effective solution. Much of the quantitative benefit is widely perceived but not as often realized when life cycle system costs are carefully calculated. This is not to say that all automated systems result in increased costs. Many systems contribute to increased organizational output, which in the case of private industry can translate into increased profits. This is especially true where automation directly assists in the production of goods and end-items. It is much harder to derive a quantitative measure of increased productivity in the case of office, administrative, white collar jobs. The Government in general, and the Air Force in particular, fall into this category. Historical data and current trends are mixed in their net assessment. It is widely held within the computer profession that computer productivity enhancement is very difficult to measure, and hence it's difficult to judge its cost effectiveness (49:8;18:43-45;74:18-1).

LEVEL OF EMPHASIS

A highly visible indicator of the importance of computer related systems is the level of budget and manpower. The Air Force Automatic Data Processing (ADP) Program budget was over $1.7 billion in FY84. This includes all systems not designated as mission critical. This figure was about 1.8% of the total Air Force budget, and represented an 11.4% growth from the previous year (74:2-13). A study conducted by the Electronic Industries Association projects embedded computer hardware costs to be $3.2 billion and software costs to be $13.9 billion by 1990 (69:12). Information collected on major current and future DOD programs show that 75% to 80% have computer hardware and software components (69:13). Finally, the number of Air Force personnel authorizations, military and civilian, in computer related areas, was over 24,000 in FY-85. This includes both ADP and embedded computer application areas (74:2-5).

PROBLEMS WITH COMPUTER BASED SYSTEMS

The difficulty in successfully developing and using computer applications has been so widely publicized that a lot of space will not be dedicated to re-describing the symptoms here. To summarize: it takes too long and costs too much money to develop computer based systems that do not do what the user wants once they are fielded. No application has escaped this fate; business applications, command and control, mission support, scientific/engineering support, and mission critical areas have all fallen prey. These problems have been studied extensively, with hundreds of reports being produced by industry, academia, and government (28:--;44:--;11:--; 69:--). The possible solutions presented in these reports over the last 15 years have touched on every conceivable area of improvement. DOD and the Air Force have started a number of initiatives in several broad areas: policy and standards, technology transition, business practices, and human resources (66:--). One important factor emerges when these initiatives are examined. The emphasis has usually been on the 'what' of the problem, and not on the 'who'. Perhaps because it is the hardest area to study, human resource problems have frequently been given a lower priority than the others. Logically, this is difficult to explain, since the best technology and methods are essentially useless without qualified personnel to employ them. Chapter Six will overview some of the newer initiatives to correct this shortfall in human resources study.

THE HUMAN RESOURCE AREA

The human resource area has been identified numerous times as being critical to solving the problems of effective development and employment of computer related systems. There are essentially two aspects to the human resource situation: the deficiencies in the knowledge and skills of the current workforce, and the shortfall of personnel to do the projected level of work in the future (44:-),(64:-),(73:chap 5) (62:1).

Examples of poor job performance, inappropriate decision making, and faulty resource allocation can be found in nearly every organization with computer related responsibilities (20:chap 15). Some of these problems are evident at the highest levels of management within supposedly 'computer sophisticated' organizations. These problems can show up in various ways. Possible examples might include:

- senior computer analysts who have never written programs
- new employees with computer educations who are expected to review and comment on detailed functional requirements specifications

- software engineers who have never heard of hash codes, linked lists, binary trees, or stacks
- software technology managers who have never been involved in embedded computer system acquisitions as part of a major program
- managers who request training programs without knowledge of either the tasks performed or the subject prerequisites for the required training
- end user application developer who requires ten months of full-time, dedicated work to develop a database application using a modern microcomputer relational database system

The soundness of decision making is being questioned in a number of high interest areas such as the Ada language, personal computers, and artificial intelligence.

Although the current effort to improve the overall software crisis problems for the Department of Defense, STARS, has great potential to succeed, there are apprehensions as to its reliance on Ada as a foundation (70:11-17). Other objections to the U.S. Government emphasis on Ada have centered its size, complexity, unreliability, impracticality, etc. These observations have been made by academe and industry alike (35:--;59:39-42;58:--).

Another major area that continues to come into question is the overall control and management of microcomputers within the Government and industry. As the glimmer begins to fade on the micro as a solution to all past problems, reality has begun to appear in the computing trade publications. The problems are very common: unused systems sit on desks and in closets, sales of micros and software are declining, the number of small computer firms filing for bankruptcy is growing, promised productivity gains are not realized, and users find themselves facing the same problems that the professional computing community faced and solved years ago, audits and inspection results show waste, mismanagement, and operational ineffectiveness, and industry leaders are admitting to the oversell of the technology. Even the need for computer literacy is being questioned (34:25;49:--;48:--;50:--).

One other area of future technology promise that is coming under fire is artificial intelligence and expert systems (14:chap 11; 46:76-80).

Assuming there is a problem with adequate numbers of qualified personnel, an obvious approach would be to institute a plan of training and education. Recent studies have pointed out that the Air Force approach to computer training has been very inadequate, and is a root cause of the problems of computer related systems (62:--).

In addition to the observation that personnel resources are a problem area is the fact that improved quality of personnel may be the most important factor in successful system development.

The currently available cost models for software development indicate that the most important factor is personnel quality. (22:--;53:--). As such, it appears that this area is one to concentrate on for increased leverage in solving the problems of computer related systems.

The demand for computer science and engineering specialists in support of the Government and industry is expected to continue its increase. The ability of formal education programs to meet this demand is not very promising. Industry continues to combat this problem through use of in-house training programs (62:28-29). Many individuals working in computer related jobs do not have formal computer based educations (44:--;52:--;69:138).

Misconceptions about education and training abound in industry and Government. Examples of a lack of understanding of basic computer concepts and fundamentals of education are numerous (61:--; 26:--;77:--).

The successful attainment of objectives in computer related projects and operations, then, depends to a great degree on the presence of well-qualified personnel. The job of the Air Force commander and subordinate managers is twofold: choose the proper people to employ on the job, and provide adequate training/education to overcome shortfalls of current personnel and prepare new personnel for organization specific tasks. To accomplish these objectives requires an understanding of what the various jobs entail and what qualifies someone to work in that environment. The next chapter will address the jobs, their duties, and common qualifications. Chapter Four will focus on the important issues needed to evaluate these jobs. Chapter Five will categorize the jobs by major responsibility, and present the important personnel qualifications for those jobs.

Chapter Three

COMMON JOB CATEGORIES, DUTIES, AND QUALIFICATIONS

The Job Description Problem

Describing job categories for the purpose of establishing qualifications is difficult. If job categories are defined arbitrarily the entire usefulness of job descriptions as personnel management tools is negated. To overcome this problem commonly accepted practices for personnel management call for a detailed job analysis before defining job descriptions (80:--;8:chap 10). To do this, however, requires some level of job category and labor experience to aid the job analysis task. Furthering the problem is the fact that job analysis typically results in lists of detailed tasks that represent the job as it is currently done. For job classes with a long history and stable task definitions the process works well. How well it applies to immature professions like computer related jobs is questionable. Current policies for manpower and training require job analysis in some form. A complete job analysis, especially for the wide variety of jobs discussed here, is well beyond the scope of this study. This report provides information helpful in conducting a job analysis for computer related tasks with the end goal of defining qualifications and training/education requirements.

With the problem of describing job categories in mind, the approach taken here will present descriptions of typical jobs as defined in commercial industry, outline the job specialities presently used in the Air Force, and finally, describe the qualifications for each as commonly accepted.

There can be a great difference between a general job description, intended to fit a wide variety of positions and people, and a specific position description associated with one person in one job. This chapter will deal with general categories of jobs. This will provide a foundation for understanding the requirements of each major job type. Incorporating the information from Chapter Four with this chapter forms the basis of the resulting job responsibilities and qualifications in Chapter Five.

Industry Job Classifications

The job classifications described here are those commonly defined by the industry and the U.S. Government. The information presented below was derived from commercial (19:--) as well as U.S. Department of Labor (88:--) sources.

Data Entry Operator.

The data entry operator is responsible for operating the computer terminals and equipment used to transform data into computer readable form. In the early days of data processing this task was accomplished using keypunch machines and the familiar computer card. Today's systems employ a variety of key-to-tape, key-to-disk, optical character reader preparation and direct entry approaches. The primary task involved in data entry is the typing of information using a standard typewriter keyboard. As computer usage has become decentralized over the years, the responsibility for much data entry has been assumed by the end-user of the information. Typical requirements for data entry operators include a high school diploma and good typing skills. Training is usually provided by the employer (19:37; 88:205-207).

Computer Operator.

The computer operator is responsible for the smooth functioning of computer systems in order to efficiently accomplish the processing workload. Operators typically work in large, centralized computer installations. They perform whatever actions are necessary to bring together input data and software programs, oversee the execution of the program and insure the output is available on the appropriate media when the program terminates.

Operators are responsible for many of the small, behind-the-scene tasks such as mounting and dismounting of magnetic tapes and disk packs, loading of ribbons and paper, etc. The decentralization of computing has again had the effect of making the end-user responsible for these tasks for microcomputers in the office environment.

Operators need the ability to follow instructions and solve problems in their work environment. Training on the specific computer is required, and normally provided by the employer (19:38-44;88:205-207).

Administrative Support Functions.

There are many administrative tasks which must be accomplished in support of computer system development and operations. These functions include such jobs as production control, media librarian, programming team librarians, etc. These functions accomplish the tasks of scheduling, workload

control, document/media storage and inventory. Jobs in this area require a high school diploma. Training is provided on-the-job (19:44-46).

Support Specialists.

Another category of miscellaneous job types involve those support tasks that are specialized in nature such as user liaison, technical writer, auditors security specialists, and training instructors (19:38-60).

User liaisons serve as the interface between the end-user of an automated system and the technical developers and maintainers responsible for the system. The liaison function is used during all phases of an automated system's life cycle. With the continuing decentralization of computing, the liaison role has become even more important in the role of the information center specialist. This position is responsible for advice and assistance to end-users in their personal computing needs. A background in both data processing and business is useful for these positions (19:58).

The technical writer is primarily used to develop documentation that describes systems for developers, operators, maintainers, and users. With such a variety of audiences, the technical writer must communicate complex information to both non-technical and technical persons. The technical writer needs good writing skills, and ordinarily has a college degree (19:58).

The auditor who specializes in computer based systems functions much as the auditor of any other area, except that he must examine the integrity as well as the accuracy of an automated system. Computer based system auditors perform detailed evaluations of systems, both existing and proposed. They examine operating procedures, system effectiveness, costs, and personnel records. Auditors are usually required to have college degrees, understand accounting principles, and have strong programming and analysis skills (19:59).

Computer security specialists are responsible for defining, implementing and monitoring the precautions taken to prevent unauthorized access to hardware and software. This may be as simple as controlling access to a computer room through the use of locks to the encrypting of data sent over communication networks. Security specialists must have strong programming and analysis backgrounds, as well as training in the specific issues of computer security (19:60).

Instructors perform the full range of teaching tasks including course definition, building objectives, writing lesson plans and examinations, lecturing, demonstrating, etc. In many cases in private industry, the training specialist does not

actually serve as an instructor, but rather, defines and acquires the teaching materials and resources provided from the outside. Instructors need a background in both teaching and data processing, although industry seems to be willing to accept either as the core and provide training in the other (19:61).

Programmers.

Programming, from a computer related perspective, is the process of developing a set of instructions that tells the computer what to do. The programmer writes this set of instructions in a programming language such as BASIC, COBOL, or FORTRAN. The program accomplishes a task in support of a functional end-user. The specifications for a program are written by a systems analyst for use by the programmer. Computer programs, along with the associated data and documentation, are referred to as software.

The production of software, commonly (and incorrectly) called programming, has been one of the most studied aspects of computer based systems. The specific tasks of a programmer are complicated and too numerous to describe here in detail. The primary tasks consist of writing the program, testing it against known data sets, preparing documentation for users, operators, and maintainers, and making changes to the programs in response to user needs and program errors. Some of the most current ideas on software and its development, as related to personnel qualifications, are discussed in Chapter Four.

Programmers are often categorized by the major application area of the software they produce. The three most common categories are applications programmers, scientific programmers, and systems programmers. Applications programmers typically produce the software that supports business applications such as accounting, inventory, ledger, etc. Scientific programming is distinguished from applications programming because of the perceived need for expertise in science and mathematics. Scientific programming is usually regarded as more difficult than applications programming for this reason. The systems programmer job is regarded as the most technically involved because of its specialization in highly detailed aspects of the computer itself. Systems programmers are most often concerned with the operating system and related support software. Qualifications for programmers vary with the specialty. Application programmers are expected to have training in the use of a programming language as well as knowledge of general computer concepts. Experience or knowledge in the business application being automated is also useful. Historically, programmers have often come into the field by way of being computer operators. Scientific programming, being considered more difficult from an applications standpoint, requires a four-year degree in science, engineering, or math, as well as training in programming.

Systems programming requires a degree, most often in computer science, although this is not universal (19:46-52; 88:178-180).

Systems Analyst.

Systems analysis, as applied to computer based systems, is the study of how automation can be used to improve the operations of an organization. There are three primary tasks involved in systems analysis: understanding the current method of operation, determining what the user ultimately wants to do, and proposing a new system to accomplish this objective. A successful system analyst must thoroughly understand the application being reviewed. The analyst must be able to recommend changes in the application and specific methods to implement the changes. This involves making decisions at varying levels of detail on the design, implementation and operation of the new system. The work of the system analyst has tremendous bearing on the tasks of many other computer related positions. Programmers, for instance, use the product of the analyst to develop the actual software for a program. Operations personnel carry out their duties which depend on the specific equipment chosen by the analyst. Users depend on the delivered product to accomplish their business. The analyst, then, plays a key role in the overall development and use of computer based systems. This job specialty requires in-depth knowledge of both data processing and the application. Although a four-year college degree is normally required, there is no concensus as to the subject area. The exception to this is for math, science, or engineering systems, in which case these are the appropriate academic concentrations, respectively (19:54; 88:58-59).

Technical Experts.

There is a significant group of jobs which is highly specialized, and accomplished in support of the development, operations, use, and maintenance of computers. Among these are areas such as data base administrator, data communications expert, computer performance evaluators, engineers (electrical, computer), research scientists, etc. The primary job group of these individuals may fall rightfully into one of the previously cited categories. However, the nature of their specialization, and the resulting impact on qualifications, makes it necessary to define them separately. These positions almost universally require four-year degrees in computer science or the applicable engineering discipline (19:55-71).

Computer Service Technician.

The hardware portion of any computer based system is subject to failure. It is the service technician who is responsible for diagnosing and fixing these failures. Much of this work is done with sophisticated electronic test equipment and software. There remains a large part of the job, however, that involves maintenance of moving, mechanical parts such as the mechanisms in a printer or disk drive. The service technician specialty requires a two year associate degree in electronics as well as extensive training on the specific systems being maintained. Training is a constant requirement for the technician as system components are regularly changed out and upgraded (19:65-68;88:265-268).

Managers.

The classical functions of management, planning, organizing, staffing, control, and directing, are necessary in organizations with computer related jobs just as in any other organization. The low level manager (first line supervisor) may actually perform the same work tasks as the people being managed. The high level supervisor may be so far removed from the actual work centers that he/she is only concerned with the organization's general direction, budgets, policies, etc. A manager who has oversight responsibility for development projects does such things as tracking the status in terms of cost, schedule, and performance, assuring that the project fulfills a necessary mission and is cost-effective, monitor broad changes in the external environment that might affect the project, and insure that the products are reviewed by personnel outside the developing office (68:8). Regardless of the level, a manager is responsible for making the decisions which affect administrative as well as technical aspects of the organization and its objectives. Managers of computer oriented organizations are expected to have experience in the areas they are managing. The obvious qualifications of leadership and management skills are also a requirement (19:61-63).

End-User Computing.

In contrast to the categories of 'professional' computer related jobs,there is a large and fast growing segment of 'non-professional' activities known as end-user computing. End-user computing encompasses all tasks associated with the actual application of computer based systems at the functional user level. The term 'non-professional' implies only that the computer related tasks are not the primary job of the individual. The 'end-user' is that individual who requires the

information supplied by the system to accomplish an organization's business. End-users may be professionals insofar as their functional background is concerned, but are not computer professionals in the same sense as those categories described previously.

User functions can be broken down into two main categories: indirect and direct. Indirect use implies that the products of a computer based system are obtained through other functions (e.g. requesting a seat on an airplane through a travel agent), or entails the specifying of information for products ultimately received. The other category, direct, is the actual usage of computer equipment to obtain the desired function.

Direct usage can be further broken down into five subcategories which are important to the understanding of computer related job requirements. The distinction between these subcategories is based primarily on the degree to which tailored software development is done. These five subcategories are nonprogramming use, command level use, end-use programming, functional support, and end-use computing support.

Nonprogramming end-use is the use of software provided by others as the sole access means to the desired function and data. This access is normally provided by menu-driven, tightly controlled systems.

Command level use implies that the need to access data is on a tailored basis, and accomplished by the user at his convenience. These users must understand the data, and be able to specify, access, and manipulate it using high level command and fourth generation languages.

End-use programming involves the use of both command languages and typical procedural programming languages to obtain the desired information. This category involves primarily personal use of the computer although the programming products may be shared with other end-users.

Functional support use is sophisticated programming by end-users in a particular functional area. This category provides the majority of programs to the users within the functional area. The functional support users are viewed as informal centers of programming expertise. Although they may spend the majority of their time programming, they are considered users by themselves and other users.

End-use computing support is a service function located in a central support organization often called an 'Information Center'. The primary task is to aid all categories of end-users in the full range of end-user computing functions (30:776-784).

USAF Computer Related Job Specialties

The bulk of officially defined computer related jobs in the Air Force are described as specialties in the Information Systems (AFSC 49XX) and Scientific and Development Engineering (26XX, 27XX, 28XX) career areas. Other official categories are defined by the use of the C, D, and W prefixes. Finally, there are a number of civilian job series that are computer related.

Information Systems - Officer Specialities.

Director of Information Systems (AFSC 4996).

The Director specialty is the top level management and leadership for the Information System career field. As such, this job entails directing and implementing programs to support Air Force operational requirements. Specifically, it includes the development of policies, plans, programs, and budgets for the acquisition, installation, employment, operation and support of information systems. The Information Systems Director formulates information systems objectives, manages and directs information system programs and activities, and coordinates information systems activities. This job speciality is essentially similar to the high level management area described in the previous section. The qualifications for this specialty include a broad knowledge of information system policies and procedures for the acquisition, development, deployment, operation, and support of these systems. The category requires an undergraduate degree in information or computer science, math, science, engineering, or business with information science specialization. A master's degree in like fields is desirable. The manager must have experience as a staff officer. Training in information systems resource management is desirable (85:atch 14).

Information Systems Staff Officer (AFSC 4916).

The Staff Officer specialty consists of two major areas: middle management and true staff functions in support of higher organizational levels. In both cases, the Staff Officer category encompasses the same general areas of responsibility as other management positions. Specifically included are the functions of formulating plans and policies, defining requirements, providing staff supervision and technical advice on acquisition, design, development, test implementation, operation and maintenance. The overall requirements for the staff officer specialty are the same as for the director except that the experience must be in two or more of the other specialities described below (85:atch 14).

Information Systems Programming and Analysis Officer (AFSC 4924).

The scope of job responsibilities is both broad and deep for this specialty. The Programming and Analysis Officer analyzes requirements, designs develops, documents, tests, implements, modifies and maintains software and data bases. This job category requires specialized work such as developing data communications techniques, mathematical programming for engineering and science applications, developing performance requirements for computer based systems, and implementing security mechanisms. As part of the information system design process, the Programming and Analysis Officer advises management on alternatives to system solutions available from commercial industry. This job category is essentially a combination of the systems analyst, programmer, and technical specialist categories described previously. This specialty is primarily technical in nature, and as such requires knowledge of analysis and design techniques, programming languages, test approaches, and project management. In addition, knowledge of database systems, mathematical modeling, performance analysis, or data communications is mandatory. An undergraduate degree in computer science, information science, engineering, science, math, or business with computer science specialization is required. Advanced degrees are desirable. Experience in performing the duties of the specialty, as well as basic specialty training are required (85:atch 14).

Information Systems Engineer (AFSC 4934).

The Information Systems Engineer applies engineering principles in the design, acquisition, implementation and maintenance of systems. The category includes acquisition management activities such as preparing technical specifications, reviewing and evaluating contractor proposals, and serving as technical representative to the contracting officer. As a professional engineering specialty, this category requires an undergraduate degree in electrical or computer engineering, with a graduate degree desirable. Knowledge of electronic devices, electromagnetic waves, computation, information systems, networks, communications, radar, and policies is mandatory. Experience in the specialty duties and completion of a basic training course are required (85:atch 14).

Information Systems Officer (AFSC 4944).

The Information Systems Officer category is really three separate job definitions: operations, maintenance, plans and programs. The overall category responsibility can be summarized as managing the installation, operation, and maintenance of information system resources. The operations and maintenance shredouts are essentially management of operational facility functions. The plans and programs speciality is another staff officer type position. Knowledge requirements for the specialities cover the broad areas of information systems

technology, computer science, security, acquisition, contracting, budgeting, and facility management. An undergraduate degree in information or computer science, math, science, engineering or business with computer specialization is required. In addition to the degree requirement, completion of 12 semester hours of computer science and six hours of calculus is mandatory (85:atch 14).

Occupational Survey of Computer Systems Officer Specialty.

In June, 1983 the Air Force completed an occupational survey of the 51XX Computer Systems Officer Utilization Field. This survey provided information used in career field restructuring and training analysis. The new career field was implemented in 1984 with the combining of the 51XX and 30XX specialty areas into a single 49XX Information Systems category. Although the survey report reflects only one portion of the overall population of computer related jobs, there are some pertinent findings that are reasonably assumed to be universal and relevant to this study. The most important finding was the widespread presence of tasks involving decision making about computer based system design and development. These tasks appear in a large variety of functions such as systems analysis, management, acquisition, staff actions, etc. In addition, the survey participants indicated that they used their training fairly well in their jobs. The applications being supported are varied, but appear to be highly technical in nature: command and control, intelligence, communications, etc. Other information gained from the study will be described in Chapter Six (83:--).

Information Systems - Enlisted Specialities.

In addition to the officer job classifications, the USAF has several different categories of jobs performed by enlisted personnel. There are four primary divisions of jobs: operations, programming, program management, and maintenance.

Operations (AFSC 491X1).

As the name implies, the primary responsibility of this category is to operate computer based equipment. In addition, this classification includes auxiliary tasks such as operations planning and scheduling, setting processing priorities, system monitoring, maintaining media libraries, etc. This category incorporates the operations and administrative support functions defined in the commercial industry section. Qualifications for this area include a knowledge of the capabilities, functions, and operations of information systems equipment. A high school diploma with courses in math and typing is desirable. The mandatory training consists of an operator's course. Finally, a minimum score is required on the Air Force Electronic Data Processing Test (78:atch 27).

Programming (AFSC 491X2).

The programming specialist designs, implements, tests, and maintains computer software in support of operational requirements. This category includes most responsibilities associated with the Programming and Analysis Officer previously described. A knowledge of computers, information systems, and programming are required. Completion of appropriate programming courses is a requirement (78:atch 27).

Programs Management (AFSC 496X0).

The Programs Management specialist receives, processes, and prepares information system requirements and planning/programming documents. Other responsibilities include management of plans libraries, and requests for telephone services. This category is essentially a staff/administrative support function. Knowledge of Air Force planning, programming, and budgeting, accounting procedures, procurement, manpower, and management are mandatory. (78:atch 27).

Maintenance (AFSCs 304XX, 305XX).

Most of the hardware maintenance on business oriented computer systems is performed by contractors. There are, however, several different job categories that are responsible for diagnosis and repair of operational type systems. The specific tasks accomplished are basically the same as previously described for the commercial sector. Knowledge of computer hardware systems, and their maintenance is mandatory. Training courses in the specific systems to be maintain are required (78:atch 15).

Management (AFSCs 49199, 49690).

In addition to the actual functions described above, there are true supervisory positions for each function. These jobs are responsible for first-line and middle management functions. Requirements are basically the same as for each of the subordinate specialties. In addition, training in advanced methods, management, and leadership are required (78:atch 27).

Special Prefixes - Officer and Enlisted.

The AFSCs listed above define jobs where computer related backgrounds are the primary necessity. For those jobs requiring computer expertise, but for which the functional knowledge is more important, the C, D, and W prefixes exist. The C and D prefix identifies functional jobs where programming is necessary for officer and enlisted AFSCs respectively. The D and W prefixes are for jobs that require systems analysis work (officer

and enlisted respectively). These prefixes may be applied only to a restricted set of AFSCs (85:atch 2; 78:atch 2).

Scientific and Development Engineering Area.

This general area is distinguished from the Information Systems career area by both the application domain and the nature of the work. The Scientific and Engineering career fields are concerned primarily with the development of computer based systems to support mission critical applications. Among these are avionics, command, control and communications, intelligence, aircrew training devices, automatic test equipment, munitions, and space. The actual development of such systems is typically done by contract to private industry. The role of Air Force personnel in this environment is most often one of 'contract monitoring'. This is different from many of the Information Systems jobs where development work is actually accomplished by Air Force personnel.

Computer Research Scientist (AFSC 2625).

The Research Scientist plans, manages, and conducts projects to support the design, development, use, and maintenance of computer technology in systems. Knowledge of computer technology research, development, acquisition, and computer science is required. An undergraduate degree in computer engineering, electrical engineering, or computer science from an accredited program is mandatory. An advanced degree is desirable (85:atch 10).

Computer Systems Acquisition Manager (AFSC 2736).

The Manager plans, evaluates, and conducts research and development, acquisition and support of computer engineering programs and functions involving the design, quality assurance and test of systems. Knowledge of Air Force policies and procedures for computer resource acquisition and support is mandatory. An undergraduate degree in electrical engineering or computer science from an accredited program , business management with emphasis on computers, or math is mandatory. A master's degree is desirable (85:atch 10).

Computer Systems Engineer (AFSC 2885).

The Engineer plans, manages, and conducts design, development, operation, and maintenance of computer technology in systems. A knowledge of computer technology research, development, and acquisition policies is mandatory. A four-year degree in computer engineering or electrical engineering from an accredited program is mandatory. Master's degrees are desirable (85:atch 10).

Civilian Career Specialities.

In addition to the officer/enlisted mix, the Air Force employs large numbers of civilian personnel in computer related jobs. This section outlines the specific occupational groups as defined by the U.S. Office of Personnel Management (89:--).

Computer Operations Series (GS-332).

This series includes positions engaged in operating the control console of a digital computer system. Included in this definition is the operation of peripheral equipment. This series also includes management tasks for the operations function. Operations personnel require a knowledge of the functions of computers and the ability to read, interpret, and respond to instructions provided by documentation and by the computer (89:39).

Computer Specialist (GS-334).

The Specialist is responsible for the work necessary to design, implement, maintain systems using digital computers. This series also involves jobs where selection of computers and systems is made. This category performs tasks similar to the commercial Analyst, Programmer, and Specialist job areas. Knowledge and experience requirements are also the same. These positions do not require a four-year degree (89:40).

Computer Clerk and Assistant (GS-335).

These positions involve the data processing and support function. Clerks manage storage media, schedule computer time, maintain documentation, assist in programming, etc. These jobs require a general knowledge of computer systems and programming, although not the in-depth level required by the computer specialist (89:40).

Electrical/Electronic Engineering Series (GS-850/855).

This series defines professional engineering positions which require an application of knowledge of physical sciences and mathematics, electrical and electronic phenomena, principles and practices of electrical engineering. As a professional series, this specialty requires the appropriate undergraduate degree in engineering (89:84-85).

Electronics Technician Series (GS-856).

Positions that require basic knowledge of electronics and ability to apply it to the design, development, test and maintenance of electronic equipment. This series requires broad technical knowledge, but less than that of the engineer (89:85).

Computer Science Series (GS-1550).

Duties involve professional research to evolve new methods for digital computers. The work is responsive to problems arising from use of computers, and is concerned with the development of new fields of research. This category requires professional competence in theoretical foundations of computer software, hardware, and mathematics. A four-year degree is also mandatory for this category (89:121).

Conclusions

There are a wide variety of computer related jobs that exist both in industry and the Air Force. The spectrum of tasks performed and qualifications is very broad. There is a general correspondance between the job responsibilities in industry and the Air Force, although there are some differences in groupings and titles. Qualifications for various jobs are somewhat inconsistent based on the general descriptions of the assigned responsibilities. Detailed information on job tasks is available for a portion of the Air Force computer related positions. This information is at least partially applicable to other groups of personnel. Analysis of this data reveals a heavy presence of tasks involving decisions about the design and development of systems.

Chapter Four

FACTORS OF TECHNOLOGY AND EDUCATION

Before valid qualification guidelines can be established for any job, the fundamental concepts that affect the performance of the job must be examined. For computer related jobs this area is the one most often misunderstood and misinterpreted. This problem comes about for three reasons: the computer field as a discipline is relatively young (<40 years old) and is changing rapidly, the wholesale lack of formal education in the field greatly reduces the scope of fundamentals understanding among practitioners, and experience tends to be fairly narrow based, thereby restricting the domain of knowledge of the practitioners.

Obviously, a thorough treatment of computer fundamentals is well beyond the scope and depth of this report. What follows is a brief synopsis of some of the more pertinent topics that have a direct bearing on computer related job responsibilities and qualifications.

Fundamentals of Computer Technology.

Computer Multipliers/Augmentors.

The power of a computer based system is derived from three fundamental multipliers: speed, accuracy, and memory. Applications which do not somehow take advantage of one or more of these multipliers probably should not be automated (7:chap 2).

Hardware and Software.

Electronic hardware and software are basically interchangeable when viewed only from a functional standpoint. The real differences between hardware and software lie in the amount of time and effort it takes to develop and maintain the product crafted from each. Quality measures such as reliability are also different because hardware is physical and software is logical. Computer related systems are a careful combination of hardware and software components allocated to take advantage of their respective characteristics. The availability of general purpose digital processors at very low cost makes the design and development of systems much faster and cheaper than the days when custom logic was developed. Software is best viewed as the implementation of the policy and intelligence of a system. An often heard expression is that 'the software is the system'. The

implications of this are paramount in the development and maintenance of computer related systems, since it means that the individual involved in such activities has to understand the system from a true 'systems' perspective (5:--;13:--).

Complexity.

Computer related systems are among the most complex things ever designed and built by man. Although software complexity can be difficult to measure, it is generally accepted that large software programs are many times more complex than the computer hardware they execute on. A simple illustrator of software complexity is the often shown example of a relatively simple combination of branch instructions that would take thousands of years to exhaustively test. The failure to understand issues of complexity regularly confound the development process by inappropriate allocations and tradeoffs of resources (5:--; 11:--;13:--).

Programs, Algorithms, and Binding.

Probably the most fundamental concept of the stored program computer is the difference between a program's algorithm and its data. A program is the set of instructions which are executed to carry out the application's function. Programs are normally unchanging during their execution. Data, on the other hand, are those values used by the program instructions for input, output, and the storing of results. A set of data values may change quite often during a program's execution. Other data may have unchanging values during execution, but are re-initialized with new values for subsequent executions. The time when values are associated with a data item describes the very important concept of binding. As basic as this concept is, it is misunderstood frequently. For example, it was not until the late 1970's that the idea of 're-programmable' electronic warfare systems was used. What is interesting is that the term 're-programmable' was not even used correctly for these systems, as it referred to the ability to change the data values without changing the program (71:--).

Static and Dynamic Structures.

The terms static and dynamic are used to describe characteristics of both programs and data. Programs are dynamic in that they proceed along a path of execution depending on their logic flow. Programs also have static properties which relates to their hierarchical structure. This possession of static properties is a key to the understanding of complexity.

Likewise, data items can be static or dynamic. Although static data types are more commonly used, dynamic types provide powerful capabilities useful in many application domains (10:chaps 3,4).

Development Methodologies.

The methodology used in any development project can be the determining factor of failure or success, or at the very least, the key to effective management. A methodology defines the way a process is carried out. It is at the heart of job analysis and establishing qualifications. Methodologies are some of the least understood concepts of system development since a large segment of the computer workforce employ no methodology at all (51:14). One of the largest negative impacts on effective system development has been the prescribed use of 'false' methodologies in response to Government standards and regulations. A 'false' methodology depicts a sequence of actions and products which do not represent any natural or actual way of system development. The net result is a forced mapping of actual development procedure onto the 'false' requirements. The existence of such 'false' approaches has been studied continually but as yet has had little impact upon the way systems are developed (87:--; 6:--).

Flexibility.

One of the primary advantages to employing digital computers in modern systems is the inherent flexibility it provides. A large part of this attribute is derived from the characteristics of the software. The capabilities of systems can be changed, the policies of an organization can be changed and immediately implemented, problems with other components of a system can be negated through changes in software.

Ease of Production/Lack of Natural Constraints.

Software's flexibility is derived, in part, from the ease with which it can be physically produced. Unfortunately this ease of production is a major cause of the poor quality often found in computer based systems. Ease of production means two things: anyone with a minimal investment can write programs, regardless of how ill-conceived, and the physical production of software is simple and convenient, so much so as to contribute to errors in logic, structure, and efficiency. Much of the novice's dislike of programming languages such as Pascal, compared to BASIC, centers around this ease of production issue. Little does the novice realize that Pascal was intentionally made more difficult to use to prevent sloppy errors.

The added benefit of maintainability is accrued at the same time (7:--; 14:--; 10:chap 1).

Time/Space Tradeoffs.

The tradeoff of space for time is fundamental to the design of computer system software. Programs are often optimized for minimum run-time, but at the expense of increased memory (11:--).

Development/Use/Maintenance Tradeoffs.

Computer based systems are like any other product where tradeoffs must be made between attributes of cost/schedule/performance during the product's lifecycle. When use and maintenance factors are taken into account, development costs and schedules frequently grow. Similarly, if development cost is minimized, it can have the effect of increasing use and maintenance costs.

Data Structures and Algorithms.

A further refinement of the concept of programs, algorithms and data is that of algorithm and data structure. An algorithm is a set of instructions which accomplishes some task in a finite series of steps. A program usually consists of an algorithm chosen to implement the task in a particular way due to considerations of efficiency, correctness, size, availability, maintainability, etc. A data structure is some organization of a program's data based upon similar objectives as well as the view of the data from the perspective of the user. Contrasted with this logical structure is the physical organization within the computer chosen by the developer. Algorithms and data structures are chosen together since they interrelate and affect each other and the program as a whole (60:--).

Program Audience.

A computer program is a communication tool used by two different audiences. The first audience is the computer itself. The program provides a set of instructions and data on which the computer operates. As such, the program must be written so that its syntax and semantics are correct. Another audience is that group of humans who have to read and understand the program. Included in this group are the developers as well as the maintainers of the program. A program's size, structure, and flow affect how well it is understood (14:219).

User Interface.

Every computer based system provides some function to a user. Although correctness is obviously a desired attribute of a program, the success of a system often depends more on how user friendly the system is. The user interface design is a process which relies heavily on human factors and behavioral science considerations (14:--).

Size Effect.

The relationship between the magnitude of a computer based system and its overall life cycle cost is non-linear. One of the major contributing factors to this is the increased complexity and human limits at dealing with complexity inherent in larger systems. The primary implication of this characteristic is that human experience with small systems cannot be accurately extrapolated without large system data (55:117; 7:--).

Cost/Success Factors.

Computer based systems are complex and interact extensively with human beings. In addition, software development is largely a human activity. These considerations make it difficult to judge which of the multitude of factors have the most leverage on the cost and success of a system. As a result, the overall management of computer based system development is fraught with uncertainty. The limited history of computer system development adds to the problem, making the management task extremely difficult. Innovations in programming languages and methodology have been motivated by the belief that they will improve productivity. Unfortunately, research has been unable to confirm this (55:101; 18:43-45).

Abstraction.

Abstraction is the process of identifying the important properties of a system or process, and concentrating on these to the exclusion of others. The choice of properties depends on the purpose being served by the abstraction process. Abstracting is usually done in levels and is an important method of humans to deal with complexity. Abstraction permeates the whole of computer based system development. It is used in analysis and system design to model the system from different perspectives and

levels of detail. It is used when writing programs to separate what the system does from how it does it (10:14).

Tools.

Tools are employed during the development, use, and maintenance of computer based systems to enhance the ability of people to do a job. In fact, every computer based system could be viewed as itself a tool. Tools are of numerous types such as programming languages, compilers, editors, etc. Although they enhance productivity, tools must be employed skillfully, and cannot make up for incorrect, inefficient human work habits. Research on tool development has been emphasized even though cost models indicate that overall productivity is not enhanced significantly through the use of automated tools (55:-- ;22:--).

Models.

Every engineering profession makes wide use of models in product development except in software systems. The primary reason for this is related to the cost/benefit ratio of the model compared to the cost of building the product. As previously stated, software is easy to produce in a physical sense and while ignoring measures of quality. What actually has occurred has been the production of end products which have been successively iterated over time until they reach the desired goal. In effect, the product has served as a model, but at a much higher cost than if a model had been the original goal. Many of the newer approaches to developing software incorporate modelling in various ways. Models are another employment of the concept of abstraction.

Terminology.

The language of computer based systems seems unintelligible to the layman. What the layman may not understand is that computer 'professionals' often have a difficult time communicating with each other. There are two primary reasons. First, the wide variance in backgrounds of personnel in computer related jobs means that a common baseline of knowledge often does not exist. Second, there is a great tendency to invent new names for old concepts, thereby injecting new terminology into the environment. One area where common names and descriptions often don't match is in job titles and responsibilities. The impact on personnel management is extensive. Assessing qualifications is impossible without common terminology (19:37).

The Structured Concepts.

Another area of confused terminology has to do with the term 'structured'. Many books, articles, regulations, and standards over the last few years have explained, defined, and required structured programming, structured analysis, structured design, structured testing, structured development, etc. Unfortunately, the terms have lost their meaning with respect to the original sources of definition. The true meaning of these terms is critical to the development of computer based systems since they define methods and procedures to be followed by development teams. The original concepts are significant refinements in development methodology from the classic 'waterfall approach' (9:-- ;12:--;21:--;20:--).

Reusability.

Reusability is such an inherent feature modern production that it is taken for granted. Electronic systems are designed and built using standard components. Cars are designed and built using common parts from model to model and year to year. Software, on the other hand, is typically custom built for each application. There are many good and bad reasons for this. The increase in software component reusability is often promoted as the key to enhanced productivity. Whether or not this is true is a function of as many constraints and factors as are present in any other realm of the system design problem (70:10).

Engineering and Computer Based Systems

The development of computer based systems is essentially an engineering process, and should be managed and performed using engineering based principles. Engineering as a profession has evolved over thousands of years, and the fundamental processes involved are well understood. The methods used by engineers and the requisite knowledge and skills are well defined. Computer based system development can use the engineering model as an example to follow (11:chap 1;13:chap 1).

Engineering is broadly defined as the application of scientific theory to the design, development, and operation of practical and useful systems (2:3). The engineer is a part of a team with scientists, technicians, craftsmen and mechanics that provide society with material goods. Engineering is essentially problem solving, and is applied in all phases of a system's life: research, development, design, production, operations. Most of an engineer's creative thoughts are a result of new combinations and rearrangements of old thoughts from previous experience and schooling (2:325). The engineer exercises judgement and

constraint. Much of engineering work is devoted to making decisions. Ideally all such decisions would be made on the basis of accurate data and with the use of correct scientific methods. Reality, however, dictates that intuition and good judgement must be routinely applied. The need for experience as well as education is therefore very evident (2:481).

Engineering is one of a few fields which can accurately be described as a profession. Such a definition implies that the engineer has specialized knowledge and skill, a desire for public service, exercises good judgement, accepts a code of conduct, participates in appropriate professional groups, and has some form of legal status in the sense of certification, licensing, or registration (2:62-65).

Engineers are expected to possess certain skills and knowledge before practicing their profession. Basic abilities needed for engineering include being able to think logically, understand scientific principles and apply analytical methods, conceive, organize and complete experiments, and be able to synthesize and design. The common basis for these abilities is recognized as a broad based education with appropriate concentration in an area of speciality. In addition, the engineer is expected to continue the study of his profession while practicing it. Engineers are expected to have good interpersonal skills in communications and management since the nature of the job involves other people extensively (2:73-77). Control over the quality of education is usually provided by professional groups, such as the Accreditation Board for Engineering and Technology (24:8).

Analysis of the requirements for computer based products, the tasks involved in producing them, and the problems experienced with them point out the engineering basis for the development of such products (51:--;21:--).

Computer engineering is becoming an accepted discipline within the engineering fields. Evidence of this legitimacy is the presence of accredited educational programs (24:8) and the recent establishment of a computer engineering career specialty within the Air Force (85:atch 10).

Software, as a component of computer based systems, is also becoming recognized as an engineering discipline, although with some reservations (63:--;13:--;11:--). There are unique aspects of software which make the application of engineering principles difficult. Some of these were illustrated previously. Several good references are available that relate the problem of software from a non-theoretical standpoint (7:--;14:--). One of the most significant problems with software engineering is the lack of a well accepted methodology.

Fundamental Concepts of Learning and Psychology

Education.

There are basic principles of education which are helpful in understanding certain job qualifications. The necessity of a high quality, broad based education for engineers was previously described. Also stated was the requirement for continuing education in order to avoid obsolescence. Education theory, analysis of cognitive process, and experimental findings of learning methods provide further guidance in this area.

It has long been recognized that an integrated set of learning experiences is desirable in an education program. A learning experience is what the student does, not what the teacher does. The development of a good program is dependent on an analysis of many factors. One issue is the proper definition of the level of understanding that a student must attain. The classic framework for describing these levels is Bloom's taxonomy (4:--). The organization of learning experiences must be integrated in order to achieve the desired level and be retained. Hence, the order of courses in a curriculum (concept of prerequisites) is a factor. Organizationally, the curriculum must be ordered in a manner consistent with a student's needs, not in the order seemed logical by the expert. These two orders are often different. The permanence of learning is enhanced when the student can learn general concepts and apply them to specific situations. Another important factor is the length of time over which the learning takes place. Too short or too long a period of time can adversely affect comprehension and retention (16:--).

When developing a plan for eliminating shortfalls in knowledge and skills, the concepts of learning must be transformed into an actual learning program. The specific methods for implementing such a program are many and varied. From a broad perspective, the choice usually narrows to one of education, formal training, or on-the-job training (OJT). OJT is essentially a program where actual work experience is relied upon to impart knowledge and skills in addition to more formal classroom environments. Education and formal training are terms often used interchangeably. The differences between the two are often ignored. Several of these differences are important from the standpoint of who develops courses, and how the development is done. Training is normally employed for psychomotor skill development and lower levels of cognitive development. Education concentrates on the higher level cognitive domain. Training teaches the student to do things in an approved manner. Education is broader, teaching concepts that can be judged better or worse but not necessarily right or wrong. Training emphasizes a complete list of facts while education concentrates on a select group of opinion in addition to fact (39:94-95).

Many of the computer related job categories have successfully used training and OJT approaches as the main methods of instruction. The operations and support categories are chief among these. Training and OJT as methods have proven to be effective in these areas (15:--;3:--;19:--). Technician jobs have normally required a combination of training and education (19:67). The development categories (Systems Analyst, Programmer, Specialists) seem to have no clear-cut correct approach. On one hand, extensive training programs have been used with no precise qualifications needed (17:chap 10;88:59,180,207,268). On the other hand, there are in existence accredited undergraduate and graduate degree programs in computer science and engineering (37:--; 25:--;27:--). Previously, this paper described computer based system development as an engineering activity requiring a broad based educational background.

Assessments of various approaches to education and training and their relevance to the work environment have produced mixed results. For instance, formal classroom training has been found to be more effective than OJT for complex job types. The adequacy of the data for this study is in question, however (67:--).

The Air Force has relied too heavily on work experience to compensate for inadequate training and education. Improvements in productivity through work experience are not guaranteed if prior training and education are not accomplished (62:36).

The need for continuing education in technical areas is well recognized. Membership in professional organizations and maintaining professional reading programs are partial solutions (62:--). One obstacle to continuing education is the relatively high comprehension level required to read most professional computer periodicals. This contributes to the general finding that a college education is a prerequisite for many entry level jobs in industry (40:--).

The relevance of formal education programs in the computer area is still controversial. The overall lack of consistent, quality programs is well understood. That reason is the primary motivation for the current programs in accreditation (19:chap 4;24:--;27:--;37:--). Recent assessments of even the accredited programs casts some doubt on the ability of academe to produce the qualified graduate needed by industry (45:--;33:--).

Psychology and System Development

In addition to education, an understanding of human psychology as applied to system development is important. Psychology has been studied in three primary areas relating to computer based systems: notation, practices, and tasks.

Unfortunately studies have been inconclusive regarding the notation and practices areas. In other words, there is little scientific evidence that modern methods, languages, and tools make a real difference in development productivity. This is not to say that these advances don't have a positive impact, only that the hard evidence is lacking . There are several reasons for this. First, software development is a very difficult topic on which to do research. Second, studies have been scientifically weak. Finally, there is a general lack of appreciation of the complex nature of the programming task and the individual variability of practitioners (55:108-111). It has been assumed that the difficulty of a programming task is strongly influenced by the tools, methods, and notations used. The non-linear effects of the individual have not been adequately addressed (55:108-117).

There also has been work accomplished on the study of how developers do their job and how they learn the skills that enable this. Early efforts noted a large variation in performance of the same task between programmers of comparable experience (55:111). More intuitively, large variations between novices and experts have been demonstrated many times (1:--; 55:--; 29:--; 47:--). What has been learned about the 'true' expert is that he/she stores proven fragments of programs (algorithms, code segments, etc.), together with a set of rules about their behavior and for combining them, and indexes this information in terms of the problems for which they are appropriate . Novices, on the other hand, demonstrate less productivity because of their lack of a knowledge and experience base (55:118-119; 29:595; 1:279-281). Applications of physiological findings to computer education have appeared often in the literature (47:--).

Another area of interest with respect to psychology is the usefulness of aptitude tests in selecting personnel qualified to develop programs. Although aptitude tests are used widely, including in the Air Force (78:atch 27), analyses of the validity of these tests have been mixed. Aptitude tests have been found to be valid predictors of success in school-type situations only. In addition, they place emphasis on short-term memory skills, not the long-term ones more important to effective work. Finally, aptitude test scores can generally be improved with practice (17:170-176; 15:120; 55:113).

A final topic of interest in the area of psychological considerations is the applicability of personality types to personnel selection. Studies using the Myers-Briggs Type Indicator have shown that there is no ideal personality or cognitive style for computer professionals. A common thread, however, was the characteristic of people who are 'thinking' (versus feeling), and rely on education, training, and experience to solve problems. Another set of interesting findings was that computer professionals are stereotyped with regard to their personality. This stereotype, however, is not actually prevalent among them, even though managers tend to hire individuals based

on these preconceived personality requirements (57:137-140; 41:103-109; 17:158; 23:128-132).

Findings

Computer technology is complex and quickly changing. These technology issues have an impact on personnel qualifications because they impose a very wide domain of problems and solutions about about which the computer practitioner must make decisions.

Many of the decisions, and the knowledge on which they're based, support strongly the premise that computer based systems development is an engineering endeavor. Analogies to other engineering disciplines, principles of education, and studies of psychology al. promote the idea of a need for a more formalized system of education for compute related development jobs and an attachment of a more professional attitude toward these jobs.

Chapter Five

RELEVANT JOB TASKS AND QUALIFICATION GUIDELINES

Chapter three described the various job categories used in industry and the Air Force. These were organized around position-type descriptions. That is to say, each category was dependent upon the primary tasks associated with that job type. The job types are based upon the perception of how the work is accomplished. As previously stated, specific jobs in any organization may not correspond exactly to the general job categories of Chapter Three because of differences in organizational policy and procedures. In addition, changes in technology and its application have modified the way these job categories are viewed. For example, the improvements in system development methodology are changing the nature of many of the traditional development job tasks. Also, the expansion of end-user computing has resulted in the user being responsible for virtually all tasks associated with the use of the computer system. As a result of these factors, the approach taken in this chapter is to describe job tasks and the requisite knowledge and skills needed to perform these tasks. Again, this is done at a general level, concentrating on the most pertinent issues.

Derived Computer Related Job Task Categories

The following task descriptions are based on the information from earlier sections of this study. The intent is to define categories based on the depth and breadth of knowledge and skills needed plus the relevance to common job descriptions. It should be emphasized that a specific position in an organization will likely involve responsibility for tasks, with various levels of sophistication, from more than one of the following categories.

Operations Job Tasks.

Any task that involves the physical manipulation of electro-mechanical controls is operations oriented. The operations tasks are characterized as well-defined, finite, and easy to understand. Execution of these tasks is automatic in nature given the proper stimulus. Operators perform their tasks using little if any judgement or decision making. This level of task refers to the aspects of jobs involving mechanical actions in response to some circumstance. As such, they exist in virtually all job descriptions to one degree or another.

User Job Tasks.

The user job task consists of any task involving a computer based systems where no knowledge of the means of implementation of the automated function is necessary. In addition, all functional capability from the system is attained by the user through predefined usage methods of the system. A user may be able to change the way in which he employs system features to accomplish a given task, but cannot change those features or create new ones. Possible methods of system usage are finite in nature from the standpoint of a user. User tasks are functionally oriented. They accomplish some end objective of the organization. Knowing which system task to use to satisfy a particular objective is a responsibility of the user. Pure user tasks are essentially the same as defined for the nonprogramming end-user in Chapter Three. All computer related jobs probably involve some form of user tasks at one time or another.

Maintenance Technician Job Tasks.

These tasks consist of the classic duties of diagnosing and repair of systems which have failed and no longer operate according to specification. The intent is to limit this category to hardware maintenance because of the totally different nature of the software failure problem. Hardware maintenance tasks often consist of ones rightfully classified as the user and operator tasks defined above. Those activities involving the use of electronic and mechanical test equipment are somewhat more unique, but with the increased use of digital computer technology in much of this test equipment, the nature of the tasks become more user-like.

Administrative and Clerical Support Job Tasks.

These tasks are not unique to the computer based systems area. They involve the common responsibilities for filing, typing, keeping records, etc. The level of interaction with computer based systems and information is dependent on the specific business of the organization.

Development Job Tasks.

Any task directly related to the creation of a system is considered a development task. These activities involve decision making where the developer must evaluate a functional need and choose among alternatives the best way to implement the function using computer based technology and systems. The scope of the

decision domain may vary from narrow to broad, depending on how constrained the situation is.

Management Job Tasks.

These tasks consist of decision making activities relating to the standard management functions of planning, organizing, staffing, controlling, and directing. The domain of decision making is intentionally limited to all functions except those dealing directly with development decisions. However, decisions dealing with the execution of development tasks (e.g. schedules, personnel selection, etc.) are included. All tasks involving acquisition management of systems are considered in this category.

Staff Support Job Tasks.

This category includes any activities done in direct support of the management function tasks. In addition to the classic functions of plans, programs, budgets, etc. are the tasks of auditing, security, and business support tasks such as finance and contracting.

Qualification Guidelines

As mentioned previously, the qualifications described in this study relate mainly to the knowledge and skills gained from experience and education. Being successful in a job is dependent on much more than what the person knows or can do. Initiative, perseverance, human relations, dedication, leadership, etc. are all characteristics required in a good employee. This chapter will not deal with these kinds of qualification, but rather, will concentrate on those specific areas that deal with the unique characteristics of computer based system activities. In keeping with accepted practice and policy, the level of qualifications are maintained commensurate with the minimum necessary to perform the defined tasks. This eliminates unnecessary training, over qualifying of a position, and generally better use of resources (80:--).

Operations Job Tasks.

The limited scope of responsibility of these tasks make them suited to classic training methods for their attainment. Because of the general nature of basic computer operation concepts, and also the occurance of many specific differences in detail from

one system to another, the operation task requires general background training as well as specific system training. Experience is helpful to both the general and specific task categories. Industry and Air Force standards for operations job training have been successful, and fundamentally can be applied to this task category.

User Job Tasks.

True user tasks as defined in this chapter are adequately prepared for through the use of standard training and OJT. However, this applies only to the actual computer based system aspect of the job. If the application functions require an in-depth understanding of the application itself, then the level of knowledge will be correspondingly higher. For example, a sophisticated user, like a financial manager, might employ his automated system in a very simple fashion to obtain the needed information. However, the way he uses this information to make decisions requires much more knowledge than what simple training can provide. In other words, the level of qualification for a user is really more dependent on the requirement of the functional job held, not on the automated system usage. Users need to know how to accomplish their functional mission using a computer based tool, not how the tool itself works.

Maintenance Technician Job Tasks.

Because this task group is basically the same as the corresponding industry and Air Force specialities, the requirements for knowledge and skills are similar to what already exists. Again, it should be emphasized that a position which is responsible for maintenance will normally require user and operator tasks, and the pertinent factors from those categories also apply.

Administrative and Clerical Support Job Tasks.

These tasks have no direct interaction with computer based systems in themselves, and so require no specific qualifications other than those normally associated with such tasks. For those actual positions that do have indirect interaction, the pertinent tasks are those of another category besides this one.

Development Job Tasks.

This category of job tasks is the most complex and difficult

to define in terms of the required knowledge and skills. The two primary factors in this are the nature of the development process and how it is rapidly changing. Both of these were discussed in Chapter Four. These two factors each have a substantial effect on the determination of knowledge and skill requirements.

The massive complexity involved in the system development process is largely a product of the magnitude of the application which is being automated. There are, quite simply, no simple solutions to complex problems. The impact of this is that the simpler the function, the less knowledgeable the person needs to be to develop a system for that function. At the trivial end of the spectrum, a developer needs only to choose a commercially available product which is then used on existing equipment, with existing personnel, requiring no operations or user training, and matches the desired functionality with no modifications. The opposite end of the spectrum involves the creation of new user functions, new hardware, new software, extensive training, facilities, money, etc. The level of expertise required is obviously different between these two.

Another important issue in the nature of development is the role of application knowledge. As previously described, the application function of a computer based system is the foundation of the development effort. Not only does the developer need to thoroughly understand the application, but the definition of that application is very difficult, even by functional personnel.

There are two ramifications of the rapidly changing nature of development. First, the dynamics themselves dictate that developers be able to remain current as the technology changes. To do this requires that developers have a broad enough knowledge and experience base to make this additional information meaningful. Second, the direction of change in development technology is towards both a level of complex sophistication for dealing with very large problems, and a high level capability for end-user development. Both directions allow for a more productive development environment. The problem remains, however, to be able to distinguish where each class of developers (user and professional) is best employed.

The real issue involved in determining qualifications for development jobs revolves around the scope of the problem and solution domains in any development effort. If the scope is large, the decision making domain of the developer will be very large, and the knowledge and skills need to be very high. The nature of system development as engineering coupled with the theories of education dictate that the core requirement for highly complex projects be a formal education that is computer science and engineering based. Knowledge of current trends in this discipline is assumed. Also required is training in any specific techniques, tools, methods, and procedures being used. Finally, a knowledge of the application domain is necessary. Since having all these things in one individual may be difficult,

a team approach, using various sources of expertise may be needed. For those development efforts involving much more restricted solution and problem domains, the combination of end-user application expertise and user development tools can be an appropriate combination for success. In-depth knowledge of both these areas must be assumed.

Management Job Tasks.

The key requirement for management tasks is expertise in the management function. Although this most often involves knowledge of business practices, personnel management, and leadership, the requirement for knowledge in the area being managed is vital. The reason for this is obvious, especially for development areas. The functions of planning, organizing, and staffing are highly dependent on the nature of the job being accomplished by the organization. In the development arena, where the job may be done by widely varying personnel types (end-users and professionals), the need to determine which group can do the job falls on the shoulders of management. Unfortunately, one of the principles of end-user, distributed computing is that the user controls his systems and his use of the people. This is as it should be. However, if the manager does not have the expertise to make judgements about problem and solution complexity, the default method of development, by the user, will always be chosen. From this standpoint, training of high level functional managers in the recognition of complex problems and the domain of solutions may be helpful.

Staff Support Job Tasks.

Qualification for these job tasks follows the same guidelines as those for management. Any task involving a decision about development of computer based systems must be supported by the level of expertise commensurate with the scope of problem and solution domain present. In addition, there are specialized knowledge areas required for these tasks in order to fulfill the necessity of supplying management with information about that speciality.

Chapter Six

CURRENT SITUATION

Having established a set of guidelines to determine qualifications, it is now necessary to put the information into context with the human resource situation in the Air Force today. This chapter will discuss the current circumstances in terms of the numbers of computer related jobs, some qualitative assessment of the educational status of personnel in those jobs, and a brief description of current and near-term human resource programs.

Numbers of Computer Related Jobs

The Information Systems career area was formed in 1985 by merging the Computer Technology and Communications career fields. The new career field has over 36000 officer, enlisted, and civilian manpower positions. Of this total, 6600 are officers, 19000 are enlisted, and 10700 are civilians. This represents respectively, 6%, 3.8%, and 5% of the total Air Force officer, enlisted and civilian authorizations (74:--).

Figures collected in 1983 indicate that there were an additional 3200 military positions throughout the Air Force with other AFSCs having C, D, or W prefixes. Finally, the same 1983 source indicated that about 2600 additional Air Force positions were dedicated to embedded computer system activities that had other specialties besides the ones listed above (74:paper 2).

The user community, including end-user developers, can only be estimated in the hundreds of thousands. So extensive is the application of computer based systems that virtually all Air Force personnel are coming into contact with such a system on the job. The number of small computers alone numbers in the tens of thousands.

Other studies have indicated that large numbers of jobs involve detailed system development, operation, and use of computer based systems, but are not formally identified as such (53:65; 77:--).

Educational Status

The Air Force has established undergraduate degree requirements for all of its officer specialties that are officially computer related (see Chapter Three). It should be

noted that there are a variety of academic specialties that qualify an individual for the positions. Current statistics show that less than 30% of all Information Systems Officers (49XX) have a degree in computer technology (76:--). Civilian personnel in the GS-3XX series do not currently have mandatory degree requirements. The enlisted force also does not have a degree requirement.

Existing Education and Training Programs

The Air Force has an extensive program for training and education in the computer resource area. New officer accessions have mandatory degree requirements that are met by their undergraduate schools. The Air Force Academy, as one of these, has majors' programs in computer science, electrical engineering, operations research, etc. (72:42). The computer science program is currently being evaluated by the Computer Science Accreditation Board for accreditation purposes. An accredited computer engineering program is also planned (61:--). The Air Force Institute of Technology has a large program of graduate studies in computer science and engineering. Accreditation is being sought for these programs (75:--). The Air Training Command also offers a large number of training courses, taught in-house, contracted, and by other methods (81:--). Some of these courses are being revised, and other courses added as a result of an extensive study of career field needs (see below). Other sources of training and education for Air Force personnel exist at the Department of Defense Computer Institute, the Defense Systems Management College, the Naval Post Graduate School, etc.

Human Resource Programs

There are a number of significant human resource development initiatives underway to improve the overall quality of personnel in computer related jobs. These programs cover all facets of the career force.

Information Systems Career Program.

This program was initiated by the Headquarters Air Force to provide the best qualified civilian personnel to support the information needs of the Air Force. Its two objectives are to establish an information systems career structure similar to that for military personnel, and to identify and place quality performers in key positions. Part of the program involves establishing mandatory degree requirements for certain occupational series (79:--).

Information Systems Training Development Plan.

As a result of the formation of an information systems structure and career field in the Air Force, a study of training requirements was initiated. This major effort was begun in early 1985 and is to be completed by May 1986. The study is being conducted as an Instructional System Development, in accordance with AFM 50-2. The results will impact the training program for all information officers (83: -).

STARS Human Resources Area.

The Software Technology for Adaptable Reliable Systems (STARS) program is a multi-year, $250 million Department of Defense effort to improve the state of the practice in software development by an order of magnitude. A major area of STARS is that of human resources. The overall goal is to improve the performance and productivity of personnel involved in system development. The effort will assess the the current situation and develop programs in career management, training, and education to meet the desired goal. (28:--).

Project Boldstroke.

This study, conducted by the Air Staff, concluded that operational readiness could be improved significantly through increased management attention and understanding of software. As a result, a software management action plan was initiated to create an awareness of the software problem, provide training and education, and develop a comprehensive approach to managing the career areas involved in computer based systems. (86:--).

Chapter Seven

FINDINGS, CONCLUSIONS, and RECOMMENDATIONS

General Summary

Computer based systems are vital to the development, deployment, and employment of operational aerospace forces in support of United States national interests. Historically, there have been significant problems in effectively developing, using, and supporting computer based systems. Although there are many reasons for this, one of the most important is the lack of sufficient, qualified personnel to perform the necessary jobs. There are a large number of positions directly involved in some aspect of developing, using, or supporting computer based systems in the Air Force. The scope of these jobs is very broad, and is quite similar to that found in private industry. These jobs vary in the level of understanding and knowledge of computer concepts necessary to perform them well. A proper mixture of education, training, and on-the-job experience is necessary to insure that personnel are properly qualified for these positions. This mixture is determined from the tasks performed in each job, and the knowledge and skills needed to accomplish these tasks. Many jobs involving use, operations, and administrative support involve tasks that are well-defined and do not require high levels of comprehension from a cognitive standpoint. These jobs lend themselves to employment of training and experience to prepare personnel for them. Other job categories such as maintenance, management, and especially development are much more difficult to define, are complex in nature, and require high levels of comprehension to perform. A broader based educational background is necessary, in addition to specific training and experience, to effectively work in these jobs.

The systems development process is especially difficult to prepare for. The relative young age of computer based system experience and the rapid advancements in technology and methods have resulted in a wide disparity between the common methods of practice and the ideals of a mature, professional discipline. In order to solve this problem, it is necessary to prepare individuals for positions of responsibility in a more structured, well defined way. This can be done by better understanding the nature of the job tasks and the technology being used, stipulating that accessions into the jobs have the proper credentials, providing specific training and experience so that the broad educational concepts can be properly applied, and insuring that the skills and knowledge are maintained throughout a career.

Specific Findings

1. User, operations, and administrative support job tasks can be performed well by personnel with the proper technical training and experience in the automated portion of the system. User knowledge of the underlying application may be at a much higher level, however, requiring a more extensive training and education background.

2. Maintenance job tasks require more in-depth knowledge of the automated system, requiring extensive training or a proper broad-based educational background (e.g. two year accredited associate degree).

3. Development job tasks can successfully be accomplished only if the scope of development decisions is matched by the scope of problem and solution domain knowledge. Complex systems require broad based education plus specific training and experience. Simple systems can be developed by less knowledgeable individuals with the proper training. In both cases, however, a thorough knowledge of the underlying application is needed. The proper educational background should come from an accredited, four year degree program to insure its quality. Development technician jobs can be performed well with a combination of a two year accredited program plus training.

4. Management and staff job tasks also require broad educational backgrounds since the scope of decisions is very wide.

5. There are numerous programs in place to improve the human resource situation. Although these programs are aimed in the right direction, there is a danger that they will be based only on the tasks of computer related jobs as they now commonly exist in the Air Force. Without factoring in the elements of modern techniques and methods, these programs will not achieve their objectives. One program which is evaluating the entire spectrum of computer based system development is STARS. It must be supported and carried out if significant improvements in the personnel qualification area are to be made.

Recommendations

1. The Air Force must update its understanding of the tasks associated with computer based system jobs. This includes current methods, procedures, and tools, as well as an in-depth understanding of the underlying principles and theories. Attention and support must be given to programs such as STARS, the Software Engineering Institute, and Project Boldstroke. The

objectives of these programs must be applied across all sectors of computer based systems in the Air Force.

2. Educational requirements for personnel in computer system development jobs should be tightened to include the need for a degree in computer science and engineering from an accredited university. Because there may exist a problem in obtaining the numbers of people necessary, programs should be initiated to increase the numbers of available graduates from these programs, induce them to work for the Air Force, and provide incentives to prevent widespread turnover.

3. Current programs to modify training systems and courses must consider task and job information other than that from current methods alone. Training courses must be established in the context of an overall education and training program. Without an integrated approach, the training objectives cannot be achieved satisfactorily. Likewise, Air Force utilization of training courses must be done from a total program viewpoint. Sending someone to a course for which that person does not have the proper background is wasteful.

4. The importance of application domain knowledge must be considered in the development of training programs for system development. It may be that adequate training cannot be provided to give one individual the total scope of knowledge required. This affects the organization of development teams, possibly requiring multiple individuals (with either functional or technical background) to participate.

5. The harsh lessons of the software crisis must not be forgotten in the rapid expansion of microcomputers and end-use computing. Modern tools provide vast capabilities at high levels of abstraction, allowing developers (especially end-users) to produce systems quickly and with little computer expertise. However, the inevitable increase in size and complexity will eventually cause the problem to exceed the capabilities of the limited solution domain and/or knowledge domain. Programs like Project Boldstroke must be supported to provide guidelines to non-experts so they can make rational decisions on user controlled developments.

6. The move toward increased professional status for computer and software development personnel should be encouraged and promoted by the Air Force. The strengthening of educational requirements is one method of doing this. Use of existing certification system should be increased, with further exploration of registration and licensing being accomplished.

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